# Design Flood Estimation Uncertainty
# Is Monte Carlo the Answer?

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# Acknowledgements

**Rory Nathan, The University of Melbourne**

**Mark Babister, WMA, Sydney**

**BMT Consulting Teams**

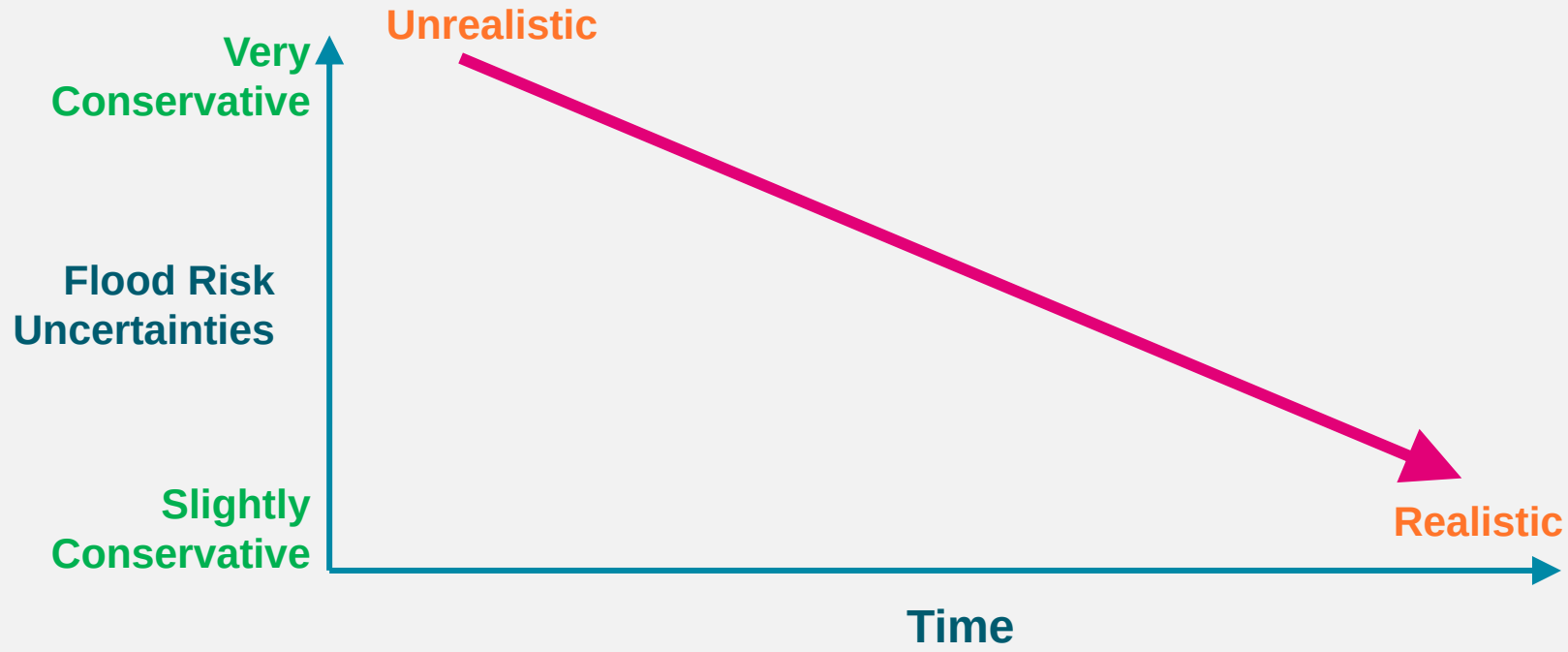
# Overview

**Australia's journey on design rainfall**

**Brisbane River Flood Study Monte Carlo Analysis**

# What are we (Modellers) all about?

## More Realistic Modelling >> Better Flood Risk Management



# Design Flood Uncertainties

## (Slide from 2018 Flood and Coast Conference – How Wrong is your Flood Model?)

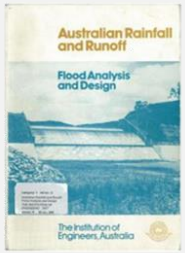
| Prime Areas of Uncertainty | Accuracy | Dependency/Target |
|---|---|---|
| Design rainfall quantity and distribution | ±10 to 50+% | Depth of historical record<br>Analysis of record |
| Topographic inputs (e.g. Ground elevations) | ±5 to 30+% | Data Quality |
| Hydrologic (catchment runoff) approach / modelling | ±10 to 50% | Complexity of approach / Calibrated? |
| Hydraulic software's mathematical solution | ±5 to 100+% | Should be <10% |
| Hydraulic model mass/timestep convergence | ±0 to 3% | Target <1% |
| Hydraulic model mesh size convergence | ±0 to 50+% | Target <5% |
| Modelling experience/quality | ±5 to 50+% | Should be <10% |
| Parameters (e.g. Manning's n) | ±5 to 20% | Calibration Quality<br>(Within Industry Standards) |

# Australia's Journey to Reduce Uncertainty
# Australian Rainfall & Runoff (ARR)

**1958**

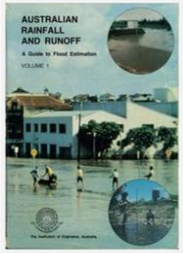

Hydro Robustus

**1977**



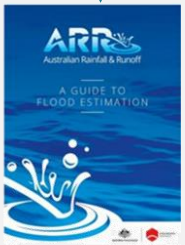

Hydro Habilis

**1987**




Hydro Erectus

**2016**




Hydro Neanderthalensis

**?**

Hydro Sapiens

- ~30 years
- 22 research projects
- 9 books (~1,500pp)
- ~£7 million & equal in-kind

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ARR Australian Rainfall & Runoff

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# Australia's Journey to Reduce Uncertainty
# Australian Rainfall & Runoff (ARR)

**1958** — Very Simple

All inputs fixed

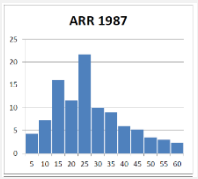
Peak flow or one hydrograph per AEP

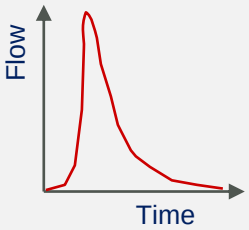
**1977** — Simple

**1987** — Simple

All inputs fixed

Single hydrograph per duration per AEP

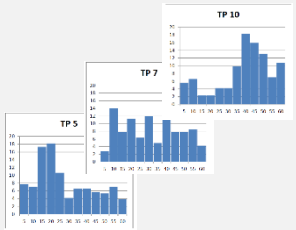


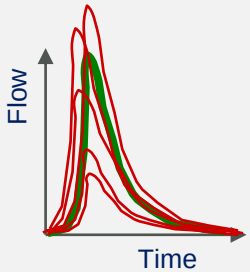




**2016** — Ensemble

Vary temporal patterns

Multiple hydrographs per duration per AEP

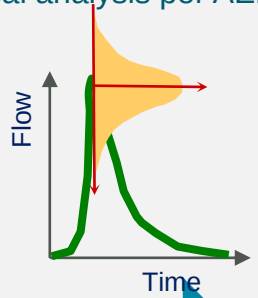



**?** — Monte Carlo

Vary all major factors

1,000s of hydrographs Statistical analysis per AEP




Less uncertainty / closer to reality / increasing defensibility

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# Design Rainfall
# How Much Rain? – Intensity / Frequency / Duration (IFD)

## 1987

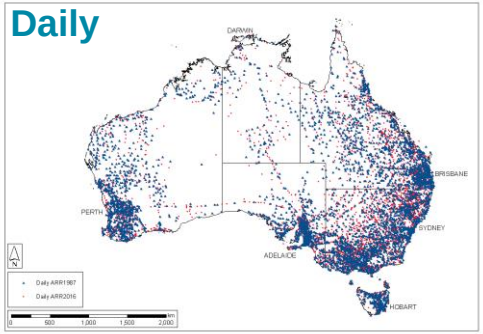
- 7,500 with 30+ years of daily records
- 600 continuous sites with 6+ years

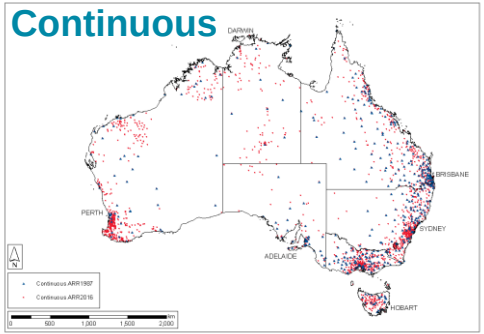
## 2016

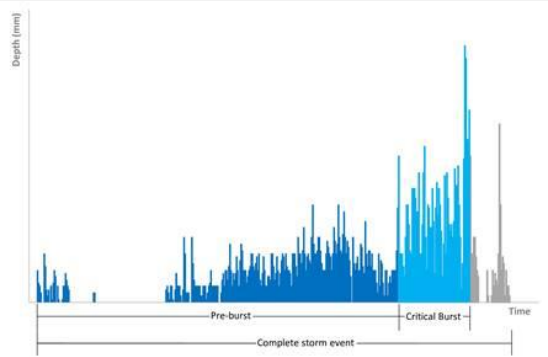
- >8,000 with 30+ years of daily records
- 2,280 continuous sites with 8+ years

**Based on critical storm burst**
**(not whole event)**

http://www.bom.gov.au/water/designRainfalls/ifd/

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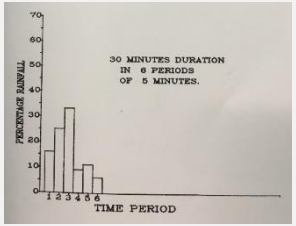
# Design Rainfall
# How Does it Fall? – Temporal Patterns

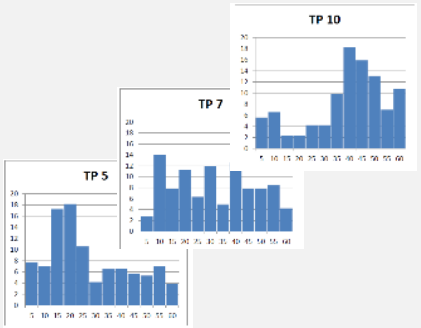
## 1987

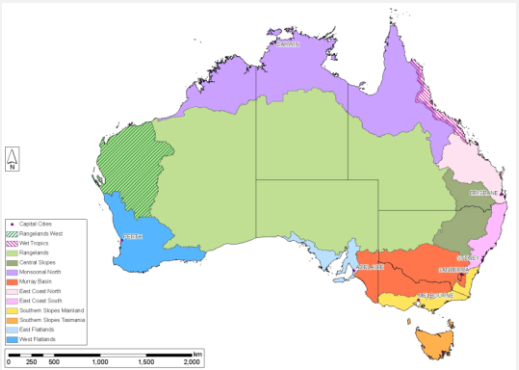
- 8 regions
- 20 durations (10 min to 72 hr)
- 1 temporal pattern per duration




## 2016

- 12 regions
- 24 durations (10 min to 7 days)
- 4 AEP bands
- 10 temporal patterns per duration per AEP band
- **Resulting in 11,000 patterns country wide sourced from 100,000's recorded storm bursts**



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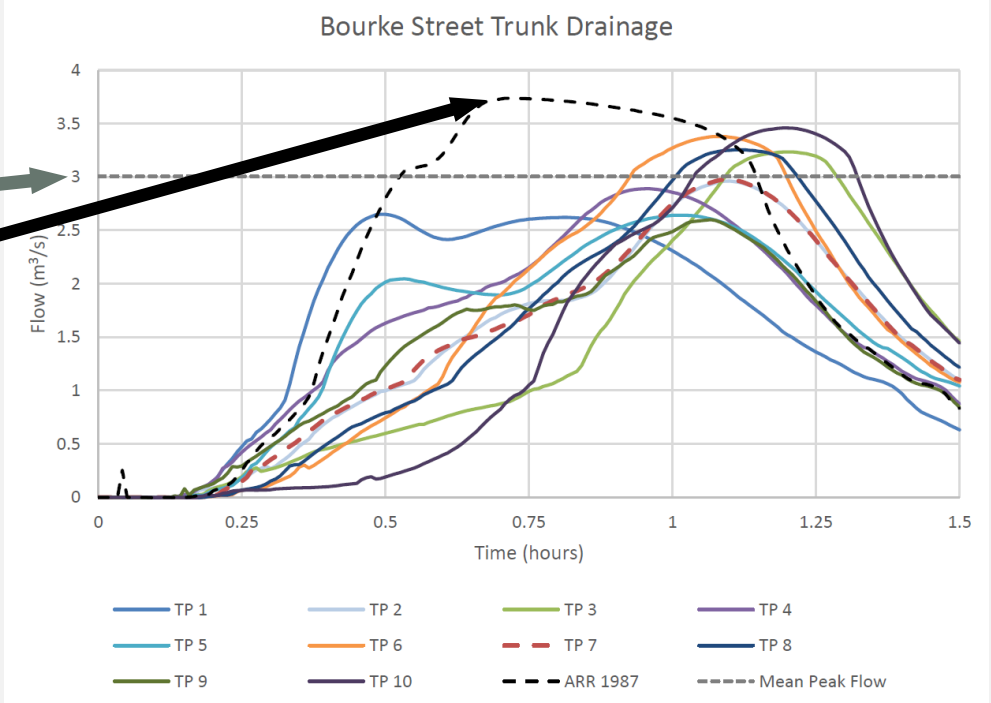
# Example of ARR 2016 Application
# Woolloomooloo, Sydney

**Chart shows the ten flow hydrographs for the 1% AEP, 60 min storm**

**Mean/Median peak flow**

**By comparison, ARR 1987**



# Observations
# ARR 2016 versus ARR 1987

**Closer to reality**

**ARR 2016 tends to produce lower levels than ARR 1987**

- ARR 2016 less conservative

**Allowance for climate change counteracting lower conservatism**

- Councils are keeping planning levels unchanged to cater for climate change

**Range of events helps quantify uncertainty**

**Greater cost, but more accurate, less uncertain outcome**

**Clarity needed on whether average flow or average level (of 10 hydrographs)**

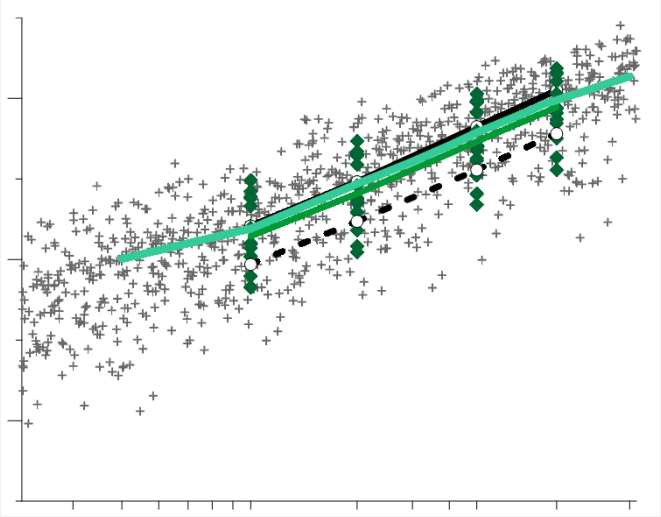
**Larger range of events helps inform other risk metrics**

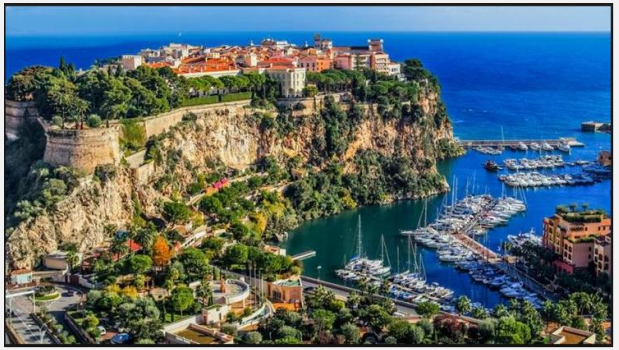
- Warning and evacuation timing, duration of flooding, etc

# Brisbane River Monte Carlo Analysis

## Question: Is Monte Carlo a

- Location in Europe
- (Very Yummy) Biscuit
- Statistical Analysis



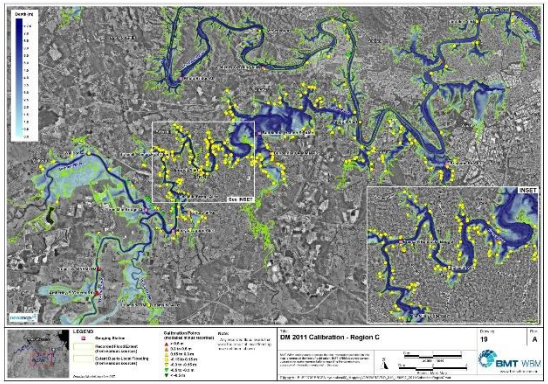


# Brisbane River – Modelling Uncertainties
# Epistemic Uncertainty (Data, Parameters)

## Very low epistemic (data, parameters) uncertainty

- Large amount of historical data from minor to major floods
  (rainfall, stream gauging, 100s of level gauges, 1,000s of flood marks)
- 50% catchment passes through Wivenhoe Dam
  (Well-defined control point)
- ADCP flow gauging in Brisbane for three major events
  (Very little uncertainty in inflows)
- Models calibrated (to death!)
  (Little uncertainty in the models from tide to 1 in 100 AEP)

## Can’t blame the model!

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# Brisbane River – Modelling Uncertainties
# Aleatory Uncertainty (Natural Variability)

## Aleatory (Natural Variability) Uncertainties

- Rainfall spatial variability
- Rainfall temporal variability
- Antecedent conditions (dry?, wet?)
- Flood storage buffer in dams (low?, high?)
- Operation of flood gates
- Ocean storm tide variability
- Climate change affects all of the above!

**Lots of (aleatory) uncertainty!**

**Need more sophistication than ARR 2016**

**Need a Monte Carlo Approach**

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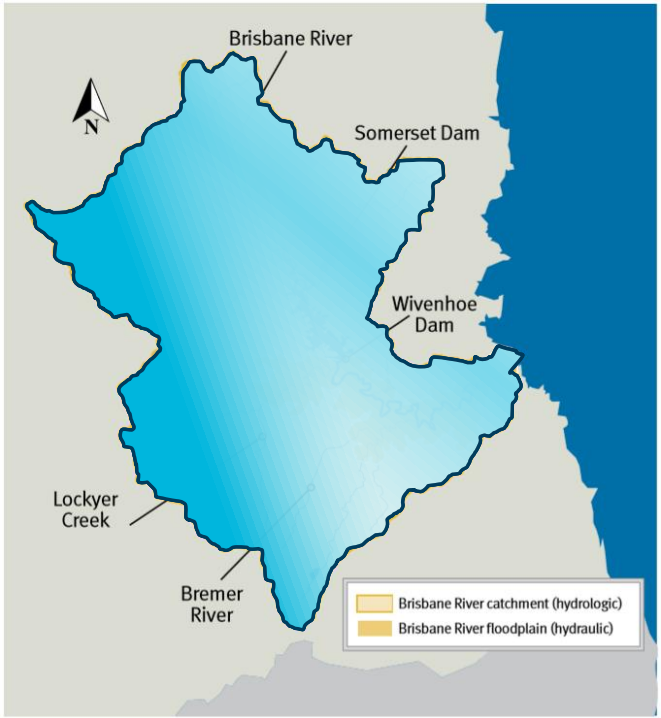
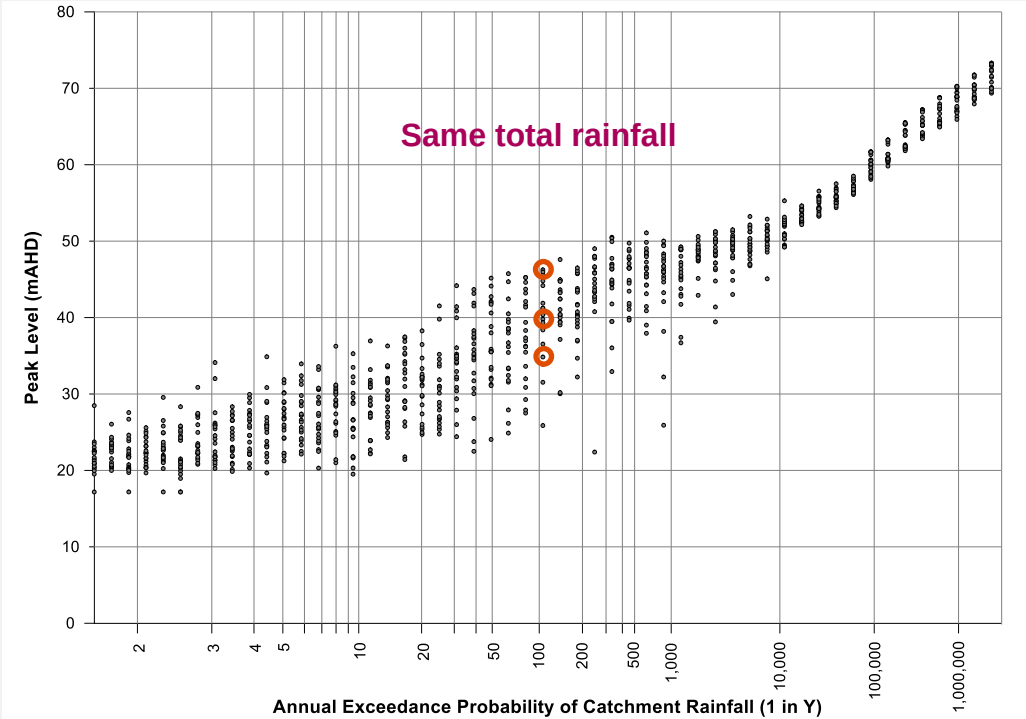
# Brisbane River
# Why Monte Carlo?

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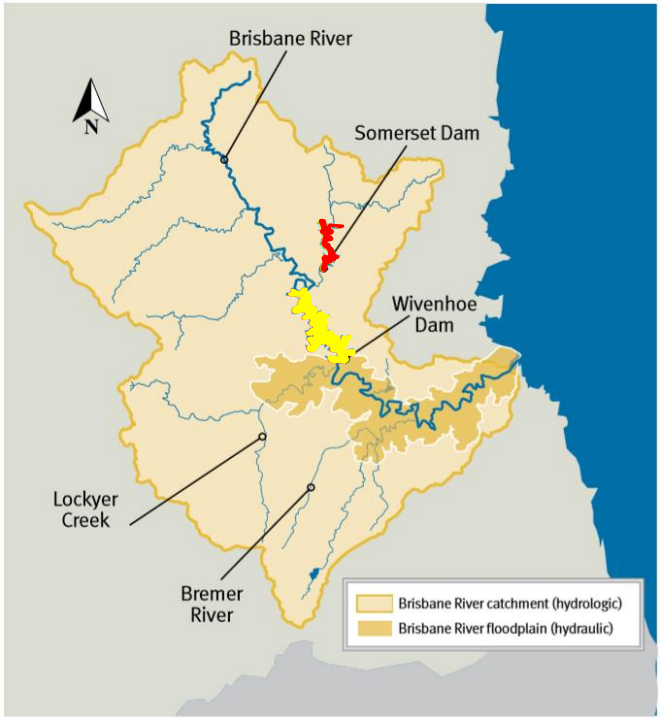
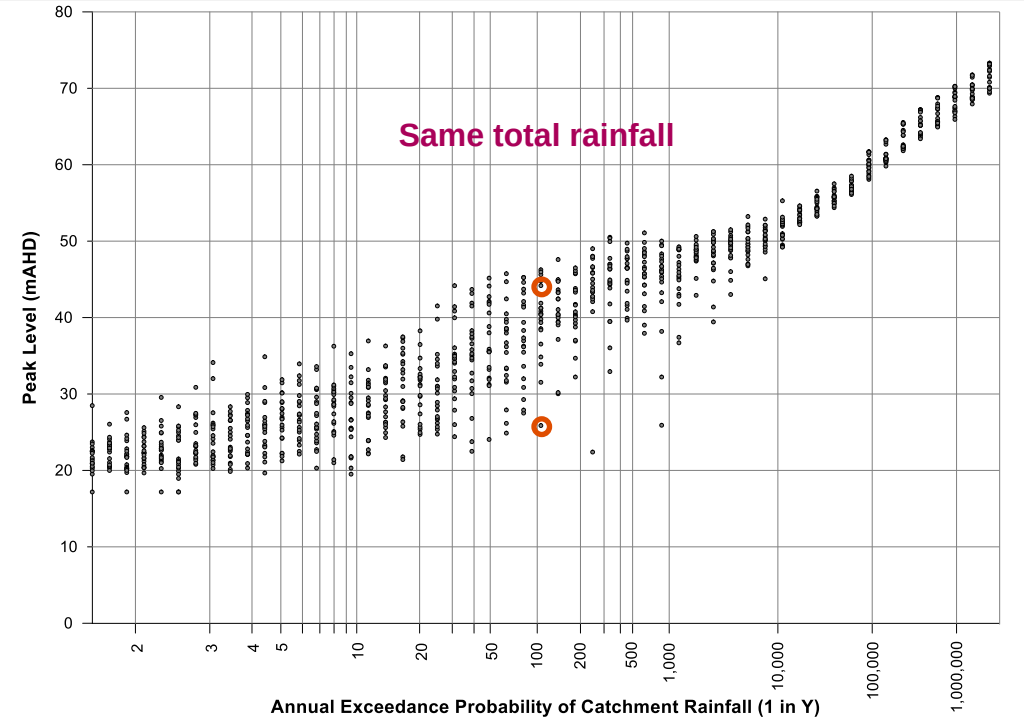
# Brisbane River
# Why Monte Carlo?



# Brisbane River
# Monte Carlo Event Simulations

**Statistically varied**
- Temporal rainfall
- Spatial rainfall
- Antecedent conditions (Infiltration losses)
- Airspace of dams
- Ocean storm tide timing and height

Hydrologic Analysis

~300,000 simulations

1D Hydraulic Analysis

11,340 simulations

2D Hydraulic Analysis

60 simulations

aurecon
Royal HaskoningDHV
Enhancing Society Together
Hydrobiology
Deltares
Don Carroll Project Management

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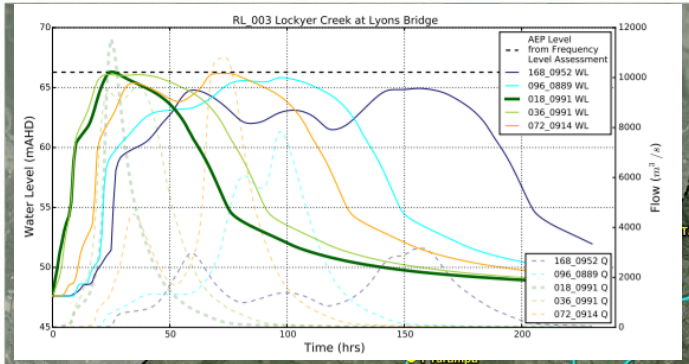
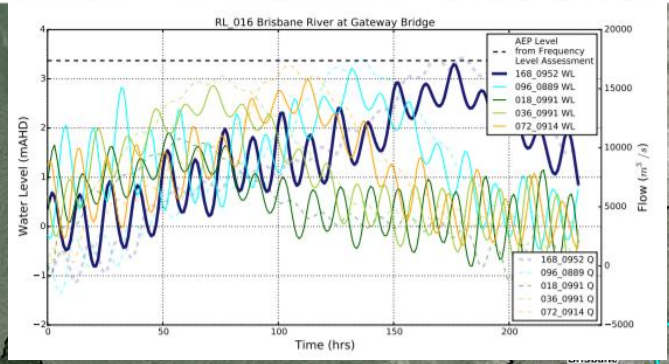
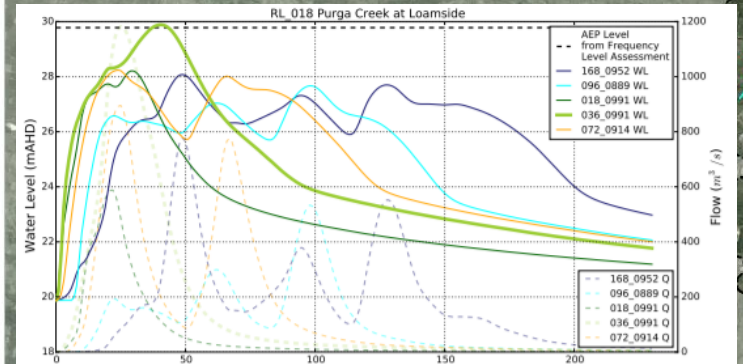
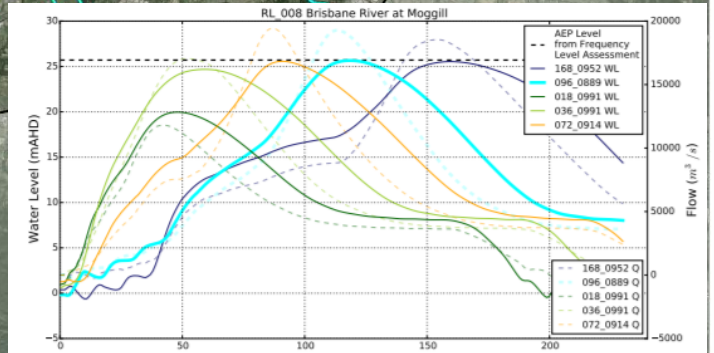

RL_003 Lockyer Creek at Lyons Bridge
Water Level (mAHD)
Flow ($m^3/s$)
Time (hrs)
AEP Level from Frequency Level Assessment
168_0952 WL
096_0889 WL
018_0991 WL
036_0991 WL
072_0914 WL
168_0952 Q
096_0889 Q
018_0991 Q
036_0991 Q
072_0914 Q


RL_016 Brisbane River at Gateway Bridge
Water Level (mAHD)
Flow ($m^3/s$)
Time (hrs)
AEP Level from Frequency Level Assessment
168_0952 WL
096_0889 WL
018_0991 WL
036_0991 WL
072_0914 WL
168_0952 Q
096_0889 Q
018_0991 Q
036_0991 Q
072_0914 Q


Tailwater
5 Savages Crossing
Fernvale
Lockyer Creek
Lyons Bridge
Lowood
4 Lowood Pump Station
66.1
Morton Vale
Glenore Grove
Brisbane River
Mount Crosby
6 Upstream Mt Crosby Weir
7 Downstream Mt Crosby Weir
Karalee
25.6
Toowong
15 Hawthorne
14 Brisbane City Gauge
13 Port Office
12 Toowong
11 Fairfield
10 Tennyson
9 Jindalee
28 Rocklea
Oxley Creek
Inala
29 Beatty Rd
3.4
Brisbane River
Gateway Bridge
19 Walloon
23 Hancock Bridge
22 David Trumpy Bridge
Ipswich
Redbank
21 One Mile Bridge
20 Three Mile Bridge
Warrill Creek
17 Amberley
8 Loamside
Purga Creek
29.9


RL_018 Purga Creek at Loamside
Water Level (mAHD)
Flow ($m^3/s$)
AEP Level from Frequency Level Assessment
168_0952 WL
096_0889 WL
018_0991 WL
036_0991 WL
072_0914 WL
168_0952 Q
096_0889 Q
018_0991 Q
036_0991 Q
072_0914 Q


RL_008 Brisbane River at Moggill
Water Level (mAHD)
Flow ($m^3/s$)
AEP Level from Frequency Level Assessment
168_0952 WL
096_0889 WL
018_0991 WL
036_0991 WL
072_0914 WL
168_0952 Q
096_0889 Q
018_0991 Q
036_0991 Q
072_0914 Q

# Conclusion

**Q: “Is Monte Carlo the answer for design flood estimation uncertainty?”**

- Reduces uncertainties – closer to reality
- Less conservative
- Very suited to more complex systems
- Australian Rainfall and Runoff 2016 approach partway Monte Carlo

**A: Yes**

**Thank you**